Natural Climate Forcing

Dr. Eugene Cordero
San Jose State University

Outline –
- Earth’s early history
- Evolution of the atmosphere
- Temperature variations
- Activity
Temperature Graph

Source:
http://www.ruf.rice.edu/~leeman/aNR.html
The graph illustrates temperature changes over thousands of years ago. Key events include:

- **Holocene maximum**: A period of high temperatures.
- **Medieval Climatic Optimum**: A subsequent period of warm temperatures.
- **Little Ice Age**: A period of cooler temperatures.
- **Younger-Dryas**: A cold period following the Holocene maximum.

The x-axis represents thousands of years ago, while the y-axis shows temperature change in °C.
Temperature and CO₂ concentration in the atmosphere over the past 400,000 years (from the Vostok ice core)
External Forcing

- 
- 
- 
-
External Forcing

- Variations in solar output
- Orbital variations
- Meteors
Solar Variations

- Sunspots correlate with solar activity
  - More sunspots, more solar energy

- Sunspots are the most familiar type of solar activity.
- Studies show the Sun is in fact about
  - 0.1% brighter when solar activity is high.
- Sunspot numbers increase and decrease
  - over an 11-year cycle
Solar Variations

- Sunspots correlate with solar activity
  - Sunspots are the most familiar type of solar activity.
  - Studies show the Sun is in fact about
  - Sunspot numbers increase and decrease
Sunspots are the most familiar type of solar activity.
Solar activity appears to slightly change the Sun’s brightness and affect climate on the Earth...
THE MAUN德尔 MINIMUM

- An absence of sunspots was well observed.

- The so-called “Maunder minimum” coincided with a cool climatic period in Europe and North America:

- The Maunder Minimum was not unique.
- Increased medieval activity
  - Higher solar activity
THE MAUN德尔 MINIMUM

- An absence of sunspots was well observed
  - from 1645 to 1715.
- The so-called “Maunder minimum” coincided with a cool climatic period in Europe and North America:
  - “Little Ice Age”
- The Maunder Minimum was not unique.
- Increased medieval activity
  - Higher solar activity
  - correlated with climate change.
Definitions

- **Insolation** – Incoming solar radiation
- **Solstice** – day of the year when the sun shines directly over 23.5°S or 23.5°N
- **Equinox** – days of the year when the sun shines directly over the equator
Upper limit of atmosphere
Sun angle (2)

Summer
Intense, high Sun

Winter
Diffuse, low Sun
What influences incoming solar energy?

- The Sun’s angle of incidence:
  - Lower sun angle, **less incoming energy**
  - Higher sun angle, **more incoming energy**

- Length of time the Sun shines each day:
  - Summer season, **more sun hours**
  - Winter season, **less sun hours**
Why do we have seasons?
Review questions

- On June 21\textsuperscript{st}, at what latitude is the sun directly overhead at noon?
- On September 22\textsuperscript{nd}, at what latitude is the sun directly overhead at noon?
- How many hours of daylight are present at the South Pole on February 20\textsuperscript{th}?
- Where would you expect to have longer days; 45 ° N on June 21\textsuperscript{st} or 50°S on Dec 21\textsuperscript{st}?
On June 21st, at what latitude is the sun directly overhead at noon?

1. Equator (0)
2. 23.5°N
3. 23.5°S
4. 90°N (north pole)
5. 90°S (south pole)
How many hours of daylight are present at the South Pole on February 20th?

1. 0 hours
2. 6 hours
3. 12 hours
4. 18 hours
5. 24 hours

0 of 70
On September 22\textsuperscript{nd}, at what latitude is the sun directly overhead at noon?

1. Equator (0)
2. 23.5°N
3. 23.5°S
4. 90°N (north pole)
5. 90°S (south pole)
Where would you expect to have longer days; 45°N on June 21st or 50°S on Dec 21st?

1. 45°N
2. 50°S
3. They are the same
4. Impossible to tell
Orbital changes

- **Milankovitch theory:**
  - Serbian astrophysicist in 1920’s who studied effects of solar radiation on the irregularity of ice ages
  - Variations in the Earth’s orbit
    - Changes in shape of the earth’s orbit around sun:
      - **Eccentricity** *(100,000 years)*
    - Wobbling of the earth’s axis of rotation:
      - **Precession** *(22,000 years)*
    - Changes in the tilt of earth’s axis:
      - **Obliquity** *(41,000 years)*
Earth's orbit: an ellipse

- Perihelion: place in the orbit closest to the Sun
- Aphelion: place in the orbit farthest from the Sun
Eccentricity: period ~ 100,000 years
The orbit of the Earth changes from nearly circular (eccentricity equal to 0.00) to more elliptical (eccentricity equal to 0.06). These changes occur in two broad frequency bands: one at periods of around 100,000 years and one at periods near 400,000 years.

While variations in orbital eccentricity have a small impact on the total amount of radiation received at the top of Earth’s atmosphere (ca. 0.1 percent), the primary importance of the eccentricity cycles is to modulate the amplitude of the precession cycle. When eccentricity is high (more elliptical), the effect of precession on the seasonal cycle is strong. When eccentricity is low (more circular), the position along the orbit at which the equinoxes occur is irrelevant since all points on the orbit become, in effect, perihelion.
Precession: period ~ 22,000 years

Like a spinning top, Earth's axis of rotation "wobbles," so that the North Pole describes a circle in space.

The 'wobble' of the Earth's axis causes the precession of the equinoxes. As shown in this figure, the positions of the equinoxes and solstices shift slowly around the Earth's elliptical orbit, completing one full cycle every 22,000 years. Precession changes the time at which the Earth reaches its perihelion (the point on the orbital path closest to the Sun), serving to amplify or soften climatic seasonality.

Top view
Today: Perihelion during northern winter.
(North Pole tilted away from Sun = northern winter)
Seasonality reduced in the northern hemisphere.

5,500 years ago: Perihelion during northern spring.
Moderate seasonality in the northern hemisphere.

11,000 years ago: Perihelion during northern summer.
(North Pole tilted towards Sun = northern summer)
Seasonality increased in the northern hemisphere.

Earth on December 21

After Piazzia & Imbrie (1986/1987)
Axis tilt: period ~ 41,000 years

Earth's axial tilt varies from 24.5 degrees to 22.1 degrees at periods close to 41,000 years.

Axial tilt affects the distribution of solar radiation on Earth's surface. When the tilt is decreased, polar regions receive less sunlight; when it is increased, polar regions receive more sunlight.

After Pallas & Imbrie (1986/1987)
A summer insolation curve for 65 degrees North latitude demonstrates how variations in precession, eccentricity, and tilt have affected the amount of solar radiation reaching Earth's surface.
Temperature: the last 400,000 years
From the Vostok ice core (Antarctica)
Fig 4.5

High summer sunshine, lower ice volume
Formation of Glaciers

- Glaciers - composed of fallen snow that is compressed into a large, thickened mass of ice over many years

- Glacier Growth: When over a year snowfall (winter) is larger than snowmelt (summer)

- Glacier Decay: When over a year snowfall (winter) is less than snowmelt (summer)

- Glacier growth and decay largely influenced by summer temperatures.
Internal Forcing

- Plate tectonics/mountain building
- Volcanoes
  - Ocean changes
  - Chemical changes in the atmosphere (i.e. CO₂)
    - Natural variations
Activity

Consider the fact that today, the perihelion of the Earth’s orbit around the sun occurs in the Northern Hemisphere winter. In 11,000 years, the perihelion will occur during Northern Hemisphere summer.

A) Explain how the climate (i.e. temperature of summer compared to temperature of winter) of the Northern Hemisphere would change in 11,000 years just due to the precession.

B) How would this affect the presence of Northern Hemisphere glaciers (growing or decaying)? Assume growth is largely controlled by summer temperature.
If the earth’s tilt was to decrease, how would the summer temperature change at our latitude

1. Warmer summer
2. Cooler summer
3. Summer would stay the same
4. Impossible to tell
A: How would climate change

1. Warmer winters, cooler summers
2. Warmer winters, warmer summers
3. Cooler winters, warmer summers
4. Cooler winter, cooler summer
B: How would glaciers change?

1. Glaciers would grow
2. Glaciers would decay
3. Glaciers would stay about constant
Summary: Orbital Variations

**Obliquity:**
When obliquity is high, seasonality is enhanced. In mid and high latitudes, summer sunshine increases and winter sunshine decreases. Averaged over the whole year, high latitudes receive more sunshine, while low latitudes receive less.

**Precession**
When perihelion occurs at summer solstice, the contrast between summer and winter is enhanced. When perihelion occurs at winter solstice, seasonality is weakened.

**Eccentricity**
Changes in the eccentricity of the earth’s orbit have very little effect on the annual averaged sunshine. However, it does have a large impact on the strength of the precession cycle. If the earth’s orbit is very eccentric, the timing of perihelion in the calendar year becomes more important.
Questions from our Internet Readings. Answer each question in 2-3 sentences.

1. What is the main point Hal Harvey is making in regard the economics of combating global warming?

2. How and why is Sweden planning to be world’s first oil free economy?

3. Who is James Hansen and what are the circumstances surrounding him, NASA and the Bush administration?
Over the past 2 million years, the earth has had ice sheets which have varied in size, causing alternations between ice ages approximately every 100,000 years and interglacial periods.

Record of Volume of Continental Glaciers
Over the Past $10^6$ Years

Oxygen isotope record from deep Pacific Ocean sediments